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(54) **SYSTEM AND METHOD FOR SPECIFYING AND CONTROLLING SUMP DEPTH**

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E21C 35/24 (2006.01)
E21C 27/24 (2006.01)

(52) **U.S. Cl.**
CPC *E21C 35/24* (2013.01); *E21C 27/24* (2013.01)

(58) **Field of Classification Search**
CPC E21C 35/24; G05B 2219/45004
See application file for complete search history.

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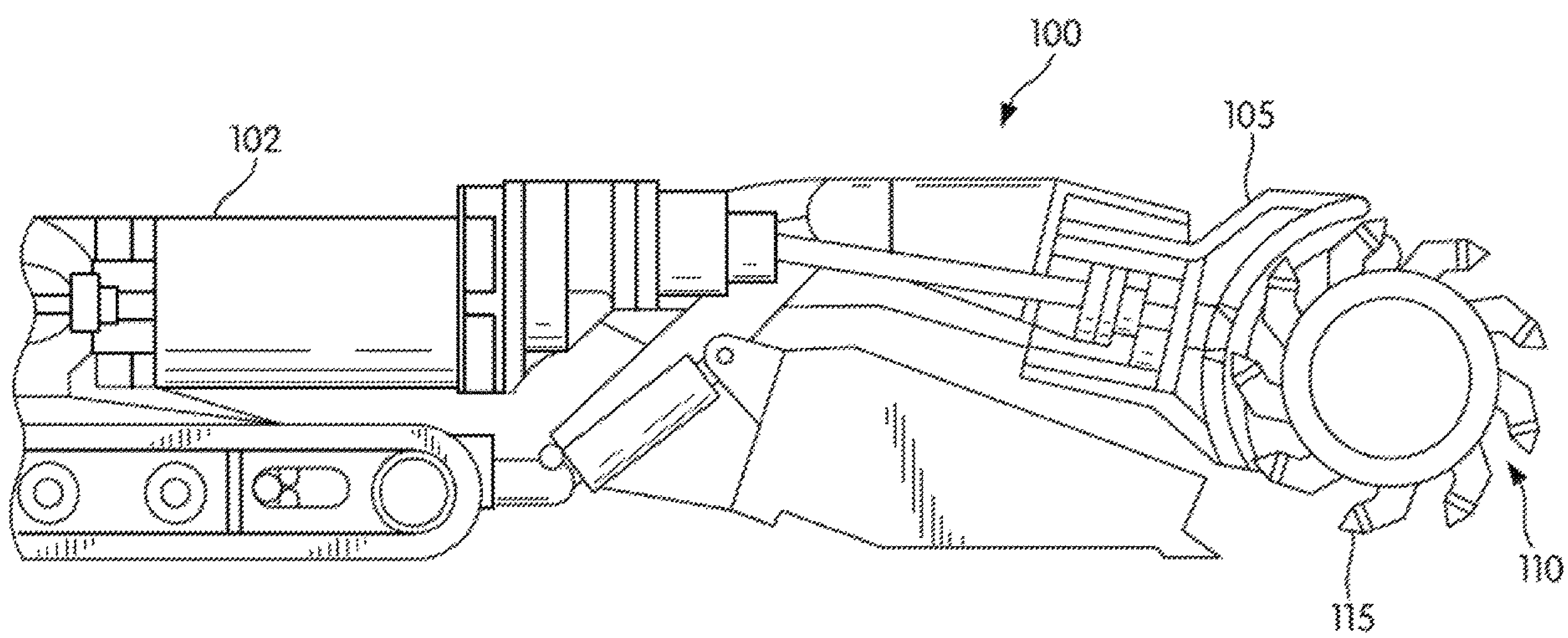
(57) **ABSTRACT**

An industrial machine comprising a chassis, a cutting head supported by the chassis, and a controller. In one embodiment, the controller, having an electronic processor and memory, is configured to receive an input via an operator, indicating at least one selected from a group consisting of a desired volume of a material to be mined and a desired weight of the material to be mined, determine a sump depth of the cutting head based on the input, and control the industrial machine based on the sump depth.

20 Claims, 4 Drawing Sheets



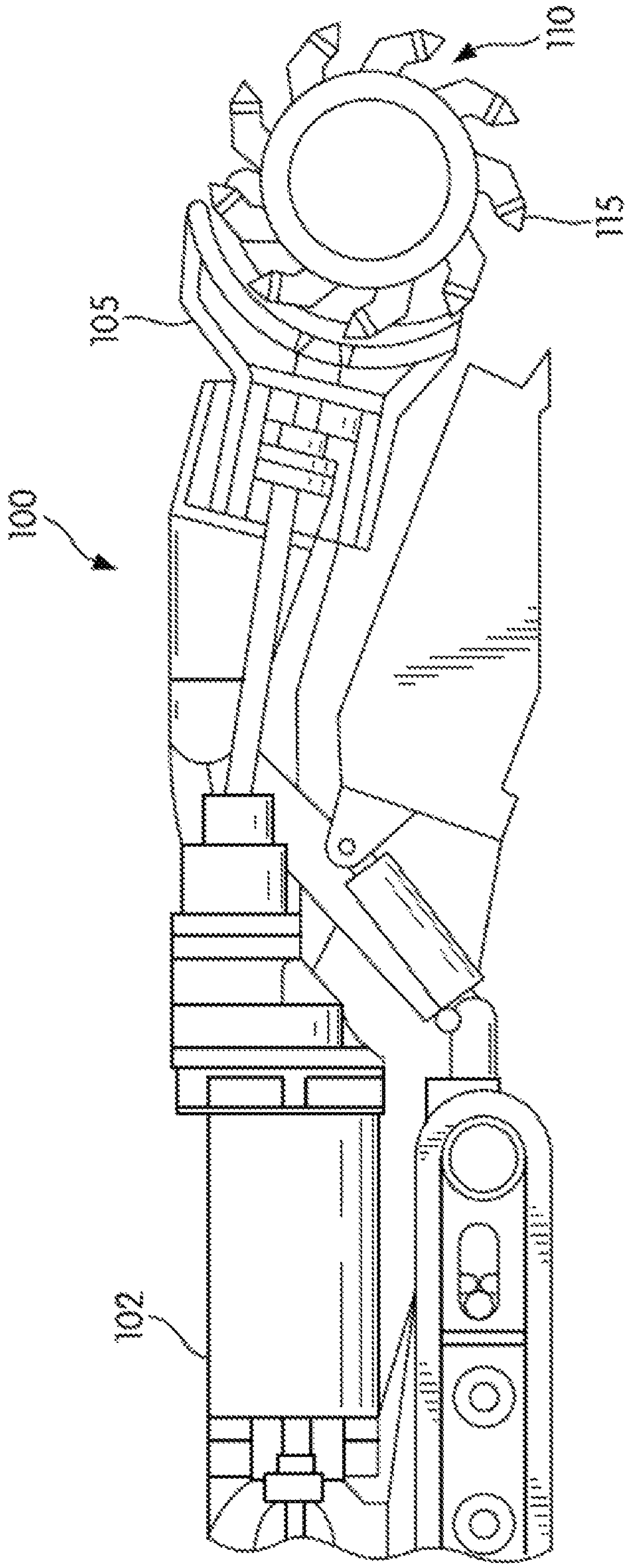


FIG. 1

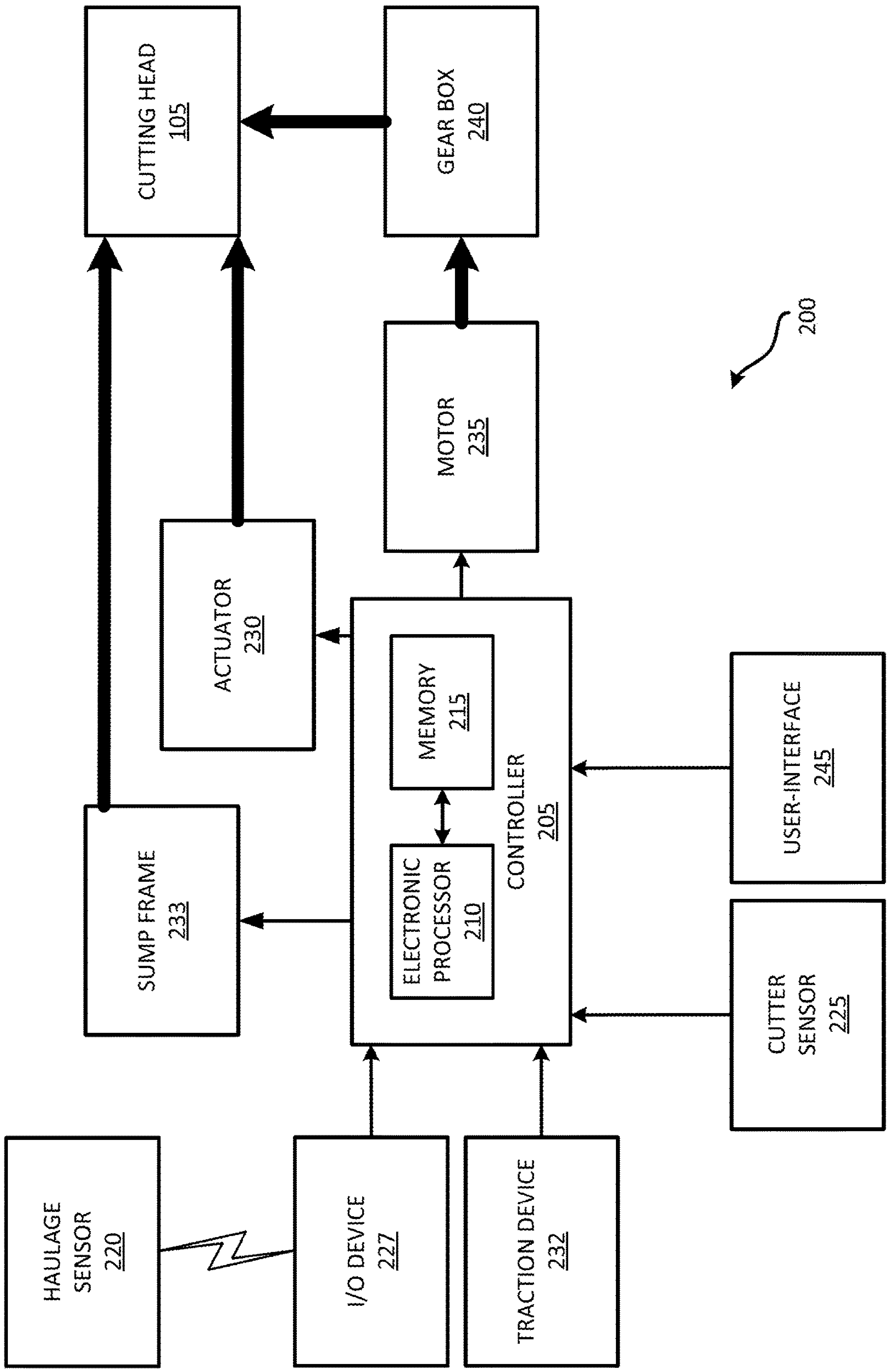

CUTTING HEAD
105
GEAR BOX
240
200
MOTOR
235
ACTUATOR
230
MEMORY
215
CONTROLLER
205
ELECTRONIC PROCESSOR
210
SUMP FRAME
233
USER-INTERFACE
245
CUTTER SENSOR
225
HAULAGE SENSOR
220
I/O DEVICE
227
TRACTION DEVICE
232

FIG. 2

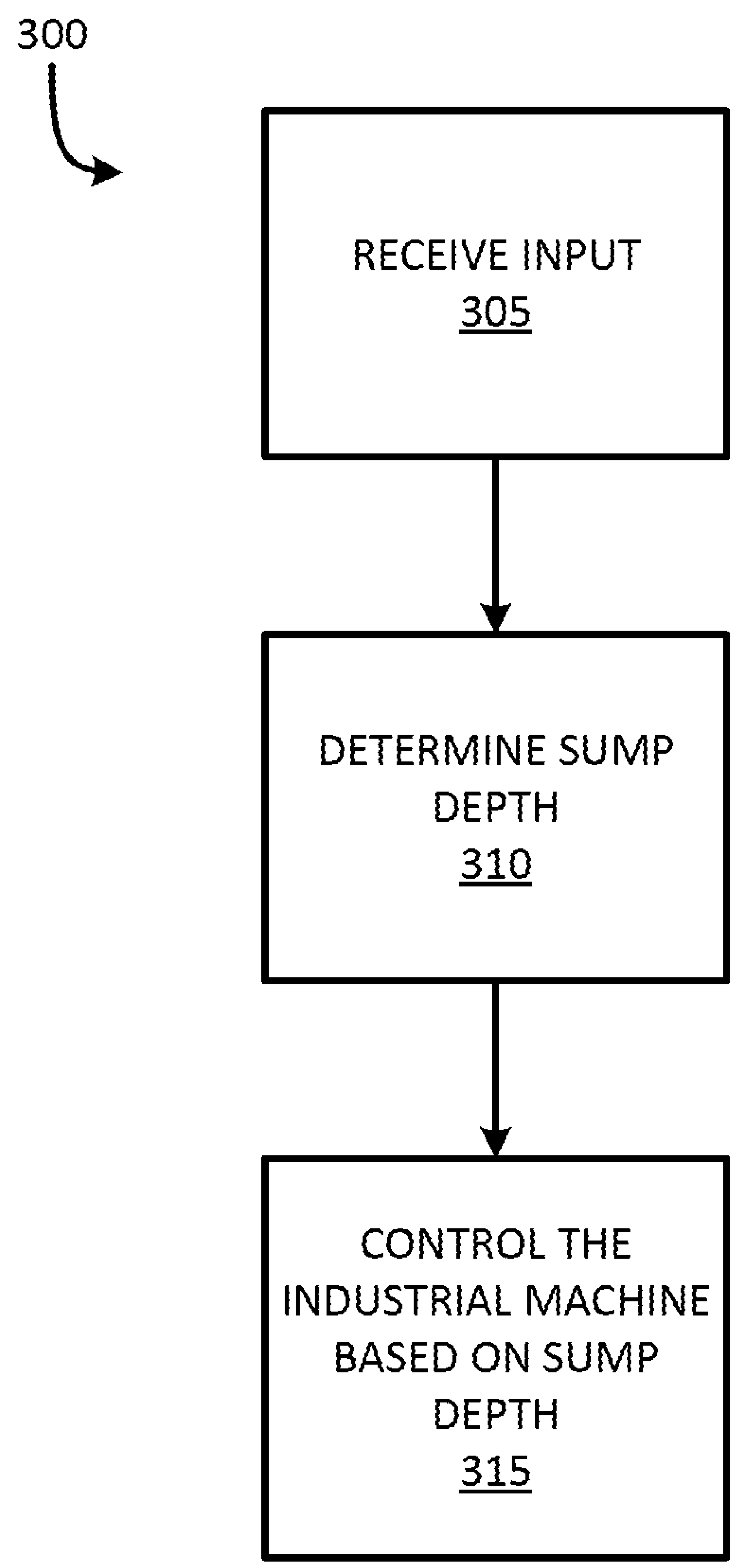

300
RECEIVE INPUT
305
DETERMINE SUMP DEPTH
310
CONTROL THE INDUSTRIAL MACHINE BASED ON SUMP DEPTH
315

FIG. 3

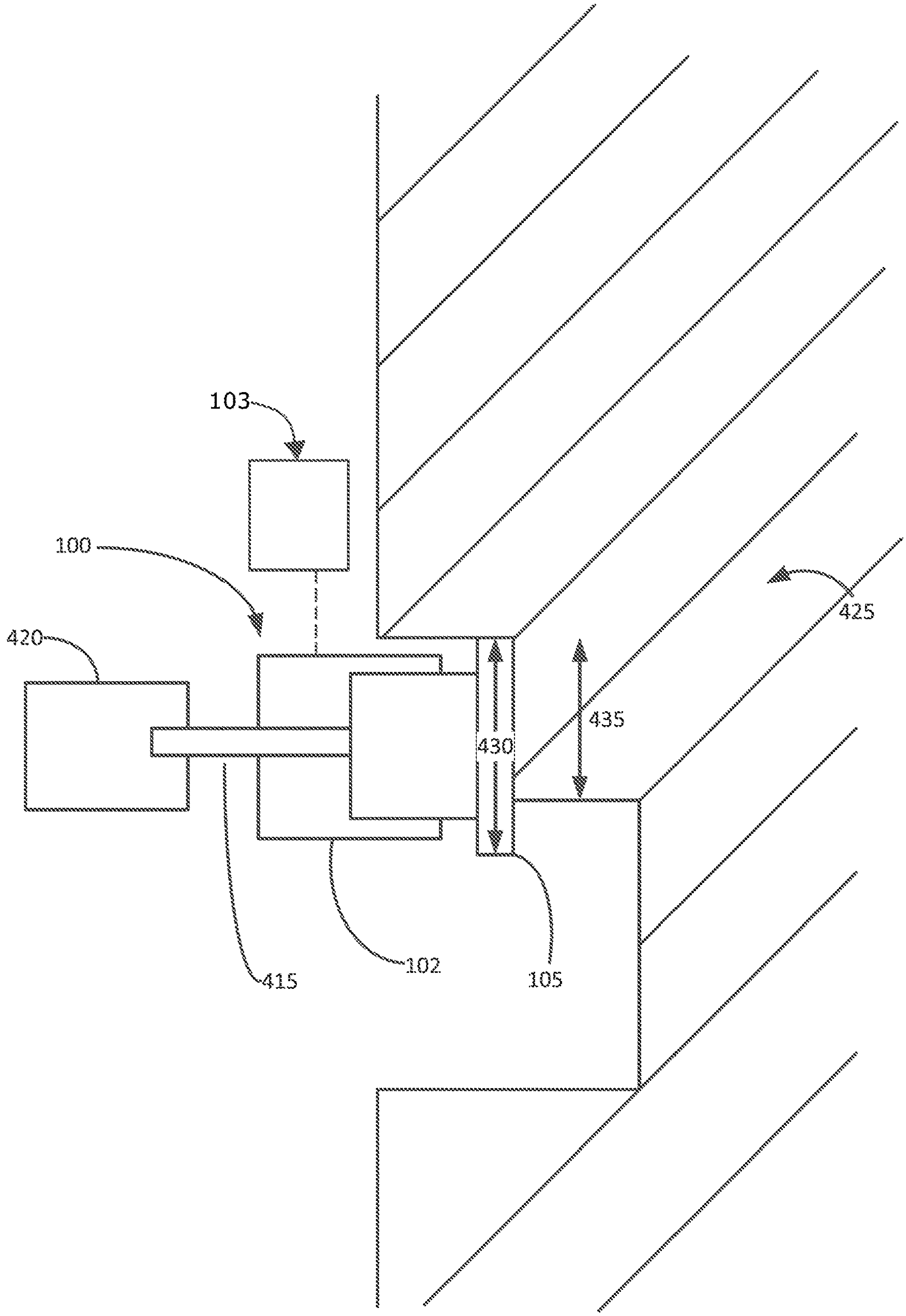


FIG. 4

SYSTEM AND METHOD FOR SPECIFYING AND CONTROLLING SUMP DEPTH

RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application No. 62/801,405, filed Feb. 5, 2019, the disclosure of which is hereby incorporated by reference.

FIELD

Embodiments relate to industrial machines.

SUMMARY

Industrial machines, such as underground mining machines, may use a plurality of cutter bits attached to a rotating cutting head in order to mine (for example, cut) material. While mining, the mined material may be unloaded into a hauling vehicle (for example, a truck) to be removed from the mining area. Currently, the sump depth, or the distance by which the industrial machine mines into the material, is visually estimated or manually measured by an operator. It would be beneficial to automatically calculate the sump depth via an electronic controller by accounting for a desired volume and/or a desired weight of the material to be mined.

Thus, one embodiment provides an industrial machine including a chassis, a cutting head, and a controller. The cutting head is supported by the chassis. The controller, having an electronic processor and memory, is configured to receive an input, via an operator, indicating at least one selected from a group consisting of a desired volume of the material to be mined and a desired weight of the material to be mined, determine a sump depth of the cutting head based on the input, and control the industrial machine based on the sump depth. In some embodiments, a sump depth advance of the industrial machine is controlled via a sump frame and/or a traction device.

Another embodiment provides a method of determining a sump depth for an industrial machine. The method includes receiving an input via an operator, indicating at least one selected from a group consisting of a desired volume of a material to be mined and a desired weight of the material to be mined, determining a sump depth of the cutting head based on the input, and controlling the industrial machine based on the sump depth.

Other aspects of the application will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a perspective view of an industrial machine according to some embodiments.

FIG. **2** illustrates a block diagram of the industrial machine controller according to some embodiments.

FIG. **3** is a flow chart illustrating a process of the industrial machine of FIG. **1** according to some embodiments.

FIG. **4** is a top view of the industrial machine of FIG. **1** and a hauling vehicle according to some embodiments.

DETAILED DESCRIPTION

Before any embodiments of the application are explained in detail, it is to be understood that the application is not limited in its application to the details of the configuration and arrangement of components set forth in the following description or illustrated in the accompanying drawings. The application is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein are for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof herein are meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings.

In addition, it should be understood that embodiments of the application may include hardware, software, and electronic components or modules that, for purposes of discussion, may be illustrated and described as if the majority of the components were implemented solely in hardware. However, one of ordinary skill in the art, and based on a reading of this detailed description, would recognize that, in at least one embodiment, the electronic based aspects of the application may be implemented in software (e.g., stored on non-transitory computer-readable medium) executable by one or more processing units, such as a microprocessor and/or application specific integrated circuits ("ASICs"). As such, it should be noted that a plurality of hardware and software based devices, as well as a plurality of different structural components may be utilized to implement the application. For example, "servers" and "computing devices" described in the specification can include one or more processing units, one or more computer-readable medium modules, one or more input/output interfaces, and various connections (e.g., a system bus) connecting the components.

FIG. **1** illustrates an industrial machine **100**, such as a mining machine, according to some embodiments. Although illustrated as a continuous miner, in other embodiments (not shown), the industrial machine **100** may be a long wall shearer, a rock crusher, or another type of mining machine. Additionally, embodiments are not limited to mining machines and may be used in conjunction with a variety of apparatuses having other types of cutting mechanisms such as oscillating discs or drill bits.

The industrial machine **100** includes a frame, or chassis, **102** supporting a cutting head **105**, which includes a rotating drum **110** with one or more cutter bits **115** for cutting material (e.g., coal, salt, or another mined material) from a surface to be mined. In the illustrated embodiment, the cutting head **105** is raised and lowered via an actuator **230** (shown schematically in FIG. **2**) and extend and retracted via a sump frame **233** (shown schematically in FIG. **2**). In other embodiments, the cutting head **105** may be advanced forward, or retracted, via one or more traction devices **232** (shown schematically in FIG. **2**) coupled to the chassis **102**. In such an embodiment, the industrial machine **100** may be advanced forward and/or retracted via the traction devices **232**. The one or more traction device **232** may include for example, tracks and/or wheels.

The cutting head **105** is rotationally driven via a gear box, or gear reducer, **240** (shown schematically in FIG. **2**), which mechanically connects to the rotating drum **110**. The cutter bits **115** may be replaceably coupled to the drum **110**.

FIG. **2** illustrates a block diagram of a control system **200** of the industrial machine **100** according to some embodiments. The control system **200** includes, among other things, a controller **205** having combinations of hardware and software that are operable to, among other things, control the operation of the industrial machine **100** and operation of the control system **200**. The controller **205** is electrically and/or communicatively connected to a variety of modules or components of the industrial machine **100**, such as, but not limited to, cutter sensor **225**, an I/O device **227**, actuator **230**, traction device **232**, sump frame **233**, and a motor **235**. As illustrated, in some embodiments, the controller **205** is further communicatively connected to a haulage sensor **220** (for example, via I/O device **227227**).

In some embodiments, the controller **205** includes a plurality of electrical and electronic components that provide power, operational control, and protection to the components and modules within the controller **205** and/or industrial machine **100**. For example, the controller **205** includes, among other things, an electronic processor **210** (e.g., a microprocessor, a microcontroller, or another suitable programmable device) and a memory **215**. The electronic processor **210** and the memory **215**, as well as the various modules connected to the controller **205** are connected by one or more control and/or data buses. In some embodiments, the controller **205** is implemented partially or entirely on a semiconductor chip.

The memory **215** includes, for example, a program storage area and a data storage area. The program storage area and the data storage area can include combinations of different types of memory, such as read-only memory ("ROM"), random access memory ("RAM") (e.g., dynamic RAM ["DRAM"], synchronous DRAM ["SDRAM"], etc.), electrically erasable programmable read-only memory ("EEPROM"), flash memory, a hard disk, an SD card, or other suitable magnetic, optical, physical, or electronic memory devices. The electronic processor **210** is connected to the memory **215** and executes software instructions that are capable of being stored in a RAM of the memory **215** (e.g., during execution), a ROM of the memory **215** (e.g., on a generally permanent basis), or another non-transitory computer readable medium such as another memory or a disc. Software included in the implementation of the industrial machine **100** can be stored in the memory **215** of the controller **205**. The software includes, for example, firmware, one or more applications, program data, filters, rules, one or more program modules, and other executable instructions. The controller **205** is configured to retrieve from memory **215** and execute, among other things, instructions related to the control processes and methods described herein. In other constructions, the controller **205** includes additional, fewer, or different components.

In some embodiments, the control system **200** may further include a user-interface **245** and/or an input/output (I/O) device **227**. The user-interface **245** may be used to control or monitor the industrial machine **100** and includes a combination of digital and analog input or output devices used to achieve a desired level of control and/or monitoring of the industrial machine **100**. The I/O device **227** may be configured to input and output data from the control system **200** to outside device(s), for example, through a network. The network may be, for example, a wide area network ("WAN") (e.g., a TCP/IP based network, a cellular network, such as, for example, a Global System for Mobile Communications ["GSM"] network, a General Packet Radio Service ["GPRS"] network, a Code Division Multiple Access ["CDMA"] network, an Evolution-Data Optimized ["EV-DO"] network, an Enhanced Data Rates for GSM Evolution ["EDGE"] network, a 3GSM network, a 4GSM network, a Digital Enhanced Cordless Telecommunications ["DECT"] network, a Digital AMPS ["IS-136/TDMA"] network, or an Integrated Digital Enhanced Network ["iDEN"] network, etc.). In other embodiments, the network is, for example, a local area network ("LAN"), a neighborhood area network ("NAN"), a home area network ("HAN"), or personal area network ("PAN") employing any of a variety of communications protocols, such as Wi-Fi, Bluetooth, ZigBee, etc. In some embodiments, the I/O device **227** may be configured to communicate with an external device via radio-frequency identification (RFID).

As discussed above, the industrial machine **100** may further include a gear box **240**. The gear box **240** is driven by the motor **235**. The motor **235** may be any motor such as, but not limited to, an alternating-current (AC) motor (e.g., a synchronous motor, an AC induction motor, etc.), a direct-current motor (e.g., a commutator direct-current motor, a permanent-magnet direct-current motor, a wound field direct-current motor, etc.), and a switched reluctance motor or other type of reluctance motor. In another embodiment, the motor **235** is a hydraulic motor, such as but not limited to, a linear hydraulic motor (i.e., hydraulic cylinders) or a radial piston hydraulic motor. In some embodiments, the mining machine **100** includes a plurality of motors **235** for operating various aspects of the mining machine **100**. In such an embodiment, the motors **235** may be a combination of AC motors, DC motors, and hydraulic motors.

Controller **205** may further be communicatively and/or electrically connected to one or more of the haulage sensor **220** and/or cutter sensor **225**, hence called the one or more sensors. The one or more sensors may be configured to sense one or more characteristics of one or more components (for example, but not limited to, the cutting head **105**) of the mining machine **100** and/or a hauling vehicle **420** (illustrated in FIG. **4**). For example, in some embodiments, the one or more sensors may be configured to sense the amount of material stored in the hauling vehicle **420** (for example, a weight of the material). In another embodiment, the sensors are configured to determine the density of the material to be mined.

The haulage sensor **220** may be configured to sense and/or determine a weight of mined material. In some embodiments, the haulage sensor is located on a haulage vehicle **420** (shown schematically in FIG. **4**) and is configured to sense a weight of mined material held, or contained, by the haulage vehicle **420**. In such an embodiment, the sensed weight is communicated to controller **205** via the I/O device **227**. In other embodiments, the haulage sensor **220** is located on the industrial machine **100** and is configured to sense a weight of mine material. In such an embodiment, the industrial machine **100** (for example, via the I/O device **227**) communicates the sensed weight to the haulage vehicle **420**.

In some embodiments, the haulage vehicle **420** may be configured to carry a predetermined capacity of mined material. In such an embodiment, the haulage vehicle **420** is configured to communicate (for example, via the I/O device **227**) the predetermined capacity to the industrial machine **100**. The industrial machine **100** may then sense, via an on-board haulage sensor **220**, the weight of material being mined, and deposit mined material to the haulage vehicle **420** corresponding to the predetermined capacity. In some embodiments, the industrial machine **100** may determine the amount of mined material using methods other than haulage sensor **220**. In such an embodiment, the industrial machine may deposit the mined material to the haulage vehicle **420** corresponding to the predetermined capacity.

In some embodiments, the industrial machine **100** is set to mine a predetermined weight of material. The industrial machine **100** may then deposit the mined material approximately equal to the predetermined weight to one or more haulage vehicles **420**.

The controller **205** may also further be communicatively and/or electrically connected to the actuator **230**. In some embodiments, the actuator **230** controls the cutting head **105** in a vertical direction (for example, raising and lowering the cutting head **105**). In one embodiment, the controller **205** uses received operator inputs to control the actuator **230**, and therefore cutting head **105**, as shown in FIG. **3**. In another embodiment, the controller **205** uses signals received by the one or more sensors to control the actuator **230**, and therefore cutting head **105**. In yet another embodiment, the controller **205** uses received operator inputs to control the motor **235** to spin the gear box **240**, therefore controlling the cutting head **1015**. For example, the one or more sensors may indicate that a material is dense (for example, above a density threshold) and send a signal to the controller **205** indicating a change in cutting speed.

The controller **205** may also be communicatively and/or electrically connected to the sump frame **233** and/or traction device **232**. In some embodiments, the sump frame **233** is an actuator (for example, but not limited to, a hydraulic actuator) configured to control the cutting head **105** in a horizontal direction (for example, in a forward and reverse direction).

In general operation, the industrial machine **100** mines material according to a sump depth. The sump depth advance of the industrial machine **100** may be varied based on the sump frame **233** and/or traction device **232** of the industrial machine **100**.

In one embodiment of operation, the controller **205** receives an input (for example, a desired mined material weight and/or a desired mined material volume). The controller **205** determines a sump depth of the cutting head **105** based on the input, and controls the cutting head **105** according to the determined sump depth. In some embodiments the controller **205** determines the sump depth based on cutting height, a cutting width, a density of the material being cut, a cutting profile of the machine, and/or a face profile (for example, a flat face and/or a curved face) of the surface to be mined. For example, the controller **205** may determine the sump depth using Equations 1 through 3 below, wherein V=volume, ρ=density, and m=mass.

$$V = CuttingHeight \times CuttingWidth \times SumpDepth \qquad \text{[Equation 1]}$$

$$\rho = \frac{m}{V} \qquad \text{[Equation 2]}$$

Solving for SumpDepth is performed by Equation 3 and solving for a SumpDepth_{adj} is performed by 4 below.

$$SumpDepth = \frac{V}{H \times W} = \frac{m}{\rho} \times \frac{1}{H \times W} = \frac{m}{\rho \times H \times W} \qquad \text{[Equation 3]}$$

$$SumpDepth_{adj} = AdjustmentFactor \times \frac{m}{\rho \times H \times W}$$

Where H=cutting height, W=cutting width, and AdjustmentFactor is a factor that may be used in adjusting the calculation of SumpDepth to cater for losses during operation of the industrial machine, measurement accuracy, etc. The AdjustmentFactor may be at least partially based on feedback information from a haulage sensor **220**.

Additionally, in some embodiments, the controller **205** may continuously and/or automatically determine a sump depth during operation of the machine **100** based on feedback from the one or more sensors. For example, the controller **205** may continuously receive sensed information concerning the cutting height, cutting width, density of the material being cut, cutting profile of the machine, and/or face profile, update the sump depth accordingly, and control the cutting head **105** according to the updated sump depth.

FIG. **3** is a flow chart illustrating a process **300** of the industrial machine **100** of FIG. **1** according to some embodiments. It should be understood that the order of the steps disclosed in process **300** could vary. Furthermore, additional steps may be added to the sequence and not all of the steps may be required.

At block **305**, the controller **205** receives an input. The input may indicate at least one selected from a group consisting of a desired volume of a material to be mined and a desired weight of the material to be mined. In one embodiment, the input is received based on an input by an operator of the industrial machine **100** (for example, via user-interface **245**). In another embodiment, the input may be stored in the memory **215**. In yet another embodiment, the input may be received from the one or more sensors. In such an embodiment, the one or more sensors may sense characteristics of one or more components (for example, the cutting head **105**, the hauling vehicle **420** (FIG. **4**), etc.).

In some embodiments, a second input may be received. The second input may indicate, for example, at least one selected from a group consisting of a cutting height, a cutting width, a density of the material being cut, and/or a cutting profile of the machine. The second input may be determined based on settings stored in the memory **215**. Alternatively, the second input may be based on a user input.

At block **310**, the controller **205** determines a sump depth (for example, using Equation 3 above). In one embodiment, the sump depth is determined based on the input received in block **305**. In another embodiment, the sump depth is determined based on both the input received in block **305** and the second input.

At block **315**, the controller **205** controls the industrial machine **100** (for example, controls a sump depth advance of the industrial machine **100**) according to the determined sump depth. In some embodiments, the industrial machine **100** is controlled via the sump frame **233** and/or the traction device **232**. For example, the controller **205** may signal to the sump frame **233** and/or the traction device **232** to extend the cutting head **105** further in order to cut more material.

In some embodiments, a tool **103** on or for use with the industrial machine **100** allows an operator of the machine to adjust the sump depth manually. In such an embodiment, the operator receives feedback corresponding to the manual adjustment (for example, feedback via user-interface **245** and/or a separate display). The feedback may be based on similar sump depth calculations discussed above. In some embodiments, the feedback provides information (for example, instructions) to the operator to manually adjust the sump depth to an optimal value. The tool **103** may be, for example, a level, a wrench, or a stick shift. In some embodiments, the tool **103** may be used in addition to or in place of step **315**.

FIG. **4** is a top view of a mining machine and hauling truck according to some embodiments. As stated above, industrial machine **100** (for example, a continuous miner) may deposit material to hauling vehicle **420** via a conveyer **415**. Conveyer **415** may be any device that allows for material to be transferred between the industrial machine **100** and hauling vehicle **420**, such as a slide, a chute, or a belt.

In some embodiments, the controller **205** is further configured to adjust the calculated sump depth due to differences in mined material between a first cutting operation and a second cutting operation. During mining operation, multiple cutting operations may occur. Each cutting operation may cut varying amounts of material and use varying amounts of the cutting head **105**, ranging from little use (approximately 1% or less) to full use (approximately 100%). For example, in a first cutting operation, material is cut using the entire width of cutting head **105**, illustrated by line **430**. During a second cutting operation, material may be cut using the width of cutting head **105** illustrated by line **435**. Line **435** may be, for example, approximately 75% of the width of line **430**. Since line **435** is shorter, cutting head **105** cuts less of the mined material during the second cutting operation. When calculating the sump depth, the controller **205** may adjusts calculations based on the differences between cutting operations (for example, a difference between a first width of material mined during a first cutting operation and a second width of material mined during a second cutting operation.

Thus, the application provides, among other things, an industrial machine and method for determining a sump depth of a mining machine based on at least one selected from a group consisting of a desired volume of a material to be mined and a desired weight of the material to be mined. Various features and advantages of the application are set forth in the following claims.

What is claim is:

1. An industrial machine comprising:

a chassis;

a cutting head supported by the chassis; and

a controller, having an electronic processor and a memory, the controller configured to

receive, via a user interface of the industrial machine, a user input indicating at least one selected from a group consisting of a desired volume of a material to be mined and a desired weight of the material to be mined,

determine a sump depth of the cutting head based on the user input, and

control the industrial machine based on the sump depth.

2. The industrial machine of claim **1**, wherein the controller is further configured to

receive a second input, the second input indicating at least one selected from a group consisting of a cutting height, a cutting width, a density of the material being cut, and a cutting profile of the machine,

wherein the sump depth is further based on the input and the second input.

3. The industrial machine of claim **1**, wherein the controller is further configured to adjust for differences in sump depth between a first cutting operation and a second cutting operation.

4. The industrial machine of claim **1**, wherein the controller is further configured to automatically adjust the sump depth based on feedback from a sensor.

5. The industrial machine of claim **1**, wherein a tool of the industrial machine allows an operator of the machine to manually adjust the sump depth.

6. The industrial machine of claim **1**, wherein the controller is further configured to provide, via the user interface, feedback on a calculation of one or more of a volume or one or more of a weight to the operator.

7. The industrial machine of claim **5**, wherein the tool is at least one selected from a group consisting of a wrench and a stick shift.

8. The industrial machine of claim **1**, wherein the industrial machine is controlled via at least one selected from a group consisting of a sump frame and a traction device.

9. A method of controlling an industrial machine, the method comprising:

receiving, via a user interface of the industrial machine, a user input indicating at least one selected from a group consisting of a desired volume of a material to be mined and a desired weight of the material to be mined,

determining, using a controller of the industrial machine, a sump depth of the cutting head based on the user input, and

controlling, using the controller, the industrial machine based on the sump depth.

10. The method of claim **9**, wherein the method further includes:

receiving a second input, the second input indicating at least one selected from a group consisting of a cutting height, a cutting width, a density of the material being cut, and a cutting profile of the machine,

wherein the sump depth is further determined on the input and the second input.

11. The method of claim **9**, further comprising adjusting for differences in sump depth between a first cutting operation and a second cutting operation.

12. The method of claim **9**, further comprising automatically adjusting the sump depth based on feedback from a sensor.

13. The method of claim **9**, wherein a tool on or for of the industrial machine allows an operator of the machine to manually adjust the sump depth.

14. The method of claim **10**, further comprising providing, via the user interface, feedback on a calculation of one or more of a volume or one or more of a weight.

15. The method of claim **13**, wherein the tool is at least one selected from a group consisting of a wrench and a stick shift.

16. The method of claim **9**, wherein the industrial machine is controlled via at least one selected from a group consisting of a sump frame and a traction device.

17. The industrial machine of claim **1**, wherein the controller is further configured to

receive a second input, the second input indicating a cutting profile of the industrial machine, wherein the sump depth is further based on the input and the second input.

18. The industrial machine of claim **17**, wherein the cutting profile of the material being cut is stored within the memory.

19. The method of claim **9**, wherein the method further includes:

receiving a second input, the second input indicating a cutting profile of the industrial machine, wherein the sump depth is further determined on the input and the second input.

20. The method of claim **19**, further comprising storing, within a memory, the cutting profile of the material being cut.

* * * * *